T-shirt Strip Dispenser

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T-shirt Strip Dispenser

There is a massive amount of waste around the textile industry. New garments are constantly being made and old garments are consistently finding themselves in landfills. This project aims to cut down on this waste. Mary Susan Ruppert-Stroescu of the Sam Fox School at Washington University in St. Louis has developed a process to turn old garments into new ones in a practice known as up-cycling. By cutting old garments into half-inch strips, laying and adhering them flat on a sheet of dissolvable paper, and sewing over them in interesting patterns she is able to create extraordinary new designs.

This project aims improve the efficiency of the laying and adhering stage of this process. It is currently the messiest and most time consuming stage. Our challenge is to create a device that is capable of laying down well-adhered fabric smoothly. The device must also operate quickly to give Dr. Ruppert-Stroescu the opportunity to increase the scale of her work.

The report that follows provides an in-depth look at the process for designing such a device. Included are insights from interviews with our customer, initial prototypes, and refined prototypes. We conclude with an analysis of the final prototype and provide areas for additional improvement of our design.

Mohsin, Syeda
Nguyen, Sabrina
Dimgba, Maxwell
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1 Introduction

On average, an American throws away 70 pounds of clothing per year, which is roughly equivalent to 191 T-shirts per person. 95 percent of wasted fabric could be recycled; however, only 15 percent of used clothing in the US is recycled or donated. In response to this wasteful epidemic, Mary Susan ruppert-Stroescu of the Sam Fox School at Washington University in St. Louis has conceptualized a method to combat material waste by re-purposing old or tattered clothing into appealing garments. This process involves cutting used garments into 1/2 inch strips of cloth and laying them down onto pre-planned patterns for sewing. Her method aims to eliminate the processing side of making material such that old cloth may be transformed into brand new garments. Furthermore, this new method would reconfigure the scope of “newness” to help forge the change in fashion towards greater ecological and environmental integrity. Our group has teamed up with Ruppert-Stroescu to prototype and fabricate a device that streamlines the tedious process of laying down strips of old t-shirts in support of sustainable garment creation.

2 Problem Understanding

2.1 Existing Devices

Existing devices with similar functionality to the device we will create.

2.1.1 Existing Device #1: Pistol Grip Dispenser with Retractable Blade

pricode=WA9375&gadtype=pla&id=H-2316&gclid=Cj0KCQjwqs3rBRCdARIsADE1pfQ0yqR0kO_jxx5DPFqV7iFywCB&gclsrc=aw.ds)

Description: This product rolls on the piece of tape down the surface it needs to tape. The blade retracts once you indicate you are done taping by shifting the weight on your wrist down. The tape rolls can be changed once it runs out. The device weighs 1.02 lbs. per unit and is equipped
with a foam handle. This provides the user with a comfortable experience, which can be useful in situations requiring extended use of the device. Rolls of tape up to, and including, 2” are supported by this dispenser. A single “Pistol Grip Dispenser with Retractable Blade” will cost the consumer $31.

2.1.2 Existing Device #2: Paper Dispenser with Cutter


**Figure 2:** Paper Dispenser (Source: Grainger Choice)


**Description:** Product Description: The product shown above holds an 18” spool of paper. The paper can be unrolled on an as needed basis and then cut by pulling it across the serrated cutting edge of the device. The cutting process is fully manual, and would require movement by either the paper, or the device itself. The wide diameter of the device provides a large work-space. The “Paper Dispenser with Cutter” retails for $84.08. The device is made from steel, providing for a durable and long-lasting product. At a shipping weight of 4 lbs, the product is light enough to be transported from one location to another.
2.1.3 Existing Device #3: Uline Manual Kraft Dispenser Tape

![Uline Manual Kraft Tape Dispenser](https://www.uline.com/Product/Detail/H-725/Kraft-Tape-Dispensers/Uline-Manual-Kraft-Tape-Dispenser?pricode=WB0079&gadtype=pla&id=H-725&gclid=EAIaIQobChMIw4P19dK_5AIVzf_jBx31ZwshEAQYASABEgI_9fD_BwE&gclsrc=aw.ds)

**Figure 3: Manual Kraft Dispenser (Source: Uline)**

Description: Product Description: The device shown above is made to dispense tape in a rapid fashion. By turning the hand crank on the side, tape is extruded from the central counsel of the device. This allows the device to produce pieces of tape that are up to 43” long. The top of the device lifts up to allow a large spool of tape to be placed inside of the device. The diameter of the tape can vary anywhere from 1.5 to 4”. Designed for high volume use with a simple, repeatable operation method. The tape cut length can be preset to allow for consistent measurements. Retail price of $279.

2.2 Patents

2.2.1 Textile Repurposing and Sustainable Garment Design (US20180125139A1)

Mary Susan ruppert-Stroescu, Elizabeth Schrantz, Carissa Elizabeth Gabilheri, and Lynae Johnice Dowdell of Oklahoma State University developed a method for eliminating material waste in apparel production. This method requires deconstructing unused scraps of fabric into various pieces (i.e. small squares and strips), treating them with an adhesive, and positioning them into specific design patterns and adhering them to a dissolvable paper that hold them in place during the sewing process.

2.2.2 Green means 4 kids attire (USRE45393E1)

This patent relates to upcycling garments. It allows use of a recycling garment that failed quality control inspections because of slight defects, to minimize textile waste. This patent relates to utilizing upcycling to make new children’s clothes from these previously mentioned unusable
fabrics. The original clothing would have been wasted but now a whole new market of upcycled children’s clothing exists.

Link: https://patents.google.com/patent/USRE45393

Figure 6: Patent Image for Upcycled Kids Attire

2.3 Codes & Standards

2.3.1 Rotating electrical machines Part 20-1 Control motors – stepping motors (CLS/TS 60034-20-1)

This standard gives requirements for motors for anyone who wants to use a rotational, central stepping motor. It also gives dimensions and information and details needed from the manufacturer. This patent only applies to rotating stepping motors. This patent enables anyone who wants to use a rotating motor to first have to use the specified dimensions and other details needed from the manufacturer. It is related to our project because we were considering adding a motor to our tool so it can very quickly roll the fabric onto its place on the piece of clothing prior to the stitching process.

Link: https://webstore.iec.ch/publication/124

2.3.2 Standard Test Methods for Rubber Deterioration – Dynatic Fatigue (ASTM D430-06)

This standard tests for dynamic fatigue caused by repeated distortions that occur in items such as tires, belts, footwear, and molded goods. These distortions can be caused by compressive and bending forces or other combinations of these. This standard also introduces two tests. Test type 1 is designed to induce separation of the rubber and fabric interface by controlled bending of the specimen. The second test is designed to produce cracking on the surface of rubber by repeated force application. This relates to our project because we may want to use rubber on our tool that rolls fabric onto its spot on the garment. In that case, we would want to consider fatigue the rubber could endure and consider this standard.

Link https://www.astm.org/Standards/D430.htm

2.4 User Needs

2.4.1 Customer Interview

Interviewee: Mary Susan ruppert-Stroescu
Setting: In a fashion studio, Mary Susan Ruppert-Stroescu gave a 15 minute presentation on her project and goals with Reclem, a movement that aims to eliminate waste in apparel production. Afterwards we asked a series of follow up questions about her current processes and their pain points. We were provided with fabric samples at the end of the meeting.

Interview Notes:

**What are you trying to achieve with your project?**
- Reinvent design, Redirect production, Rethink our possessions, Reclaim earth. This project eliminates manufacturing portion which saves cost.

**How would you compare the traditional method of garment making to methods from your project?**
- Traditional method is first designing the garment, then creating the pattern, purchasing the fabric, cutting the pattern, and sewing the garment. My project’s method is first designing the garment, creating the pattern, processing textile strips, forming them to the pattern, then sewing the garment.

**What about your project do you think needs more attention/improvement?**
- Garment collecting and sorting, the cutting process, speed and quality of laying down fabric, and overall efficiency of the process.

**What are the bare minimum wishes for this new product/tool?**
- The minimum viable would most likely look like a tool similar to a packing tape dispenser, where the dispenser spits out strips of fabric that adhere to the biodegradable paper with a sustainable adhesive. I want to find an alternative to aerosol spray. The adhesive doesn’t have to hold very long and needs to wash out easily.

**What would be stepping up from the minimum viable?**
- Something that looks like a CNC router. Maybe a way to program patterns into the computer. And a way to automatically take the strips of fabric and lay it down onto certain patterns. Also, a guide on the dispenser would be helpful.

**How long does it take you to make a skirt with your process?**
- 1 hour for cutting, 3.5 hours for laying down the fabric.

**What are the pain points of your method?**
- Knit is stretchy and curls. So paying attention to the tension of the laying process is important. Positioning and the fact that you can’t pull it as you lay it down. Once you release the fabric, it bounces back together.
2.4.2 Interpreted User Needs

The user needs a tool that easily dispenses strips of fabric and adheres them to certain, pre-planned patterns. The device should be able to switch between multiple hands. It should be easy to maneuver. The tool should also lay down the strips of fabric without causing tension in the strips. We will also hand the device to different users and observe how easy the tool is learned.

Table 1: Interpreted Customer Needs

<table>
<thead>
<tr>
<th>Need Number</th>
<th>Need</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The device should be able to move in any direction</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>The device should be durable</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>The device should be environmentally friendly</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>The device should have automation</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>The device should be aesthetic</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>The device should be portable</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>The device should be safe</td>
<td>5</td>
</tr>
</tbody>
</table>

2.5 Design Metrics

Table 2: Target Specifications

<table>
<thead>
<tr>
<th>Metric Number</th>
<th>Associated Needs</th>
<th>Metric</th>
<th>Units</th>
<th>Acceptable</th>
<th>Ideal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Degrees of freedom</td>
<td>integer</td>
<td>≥ 1</td>
<td>= 3</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Number of drops from hip height onto hard surface before malfunction</td>
<td>integer</td>
<td>&gt; 10</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>Rubber deterioration tests in ASTM D430 - 06(2018) (ASTM) ASTM International</td>
<td>binary</td>
<td>N/A</td>
<td>Pass</td>
</tr>
<tr>
<td>4</td>
<td>3, 7</td>
<td>Known environmental toxins used in production of device</td>
<td>integer</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>Number of self-moving parts</td>
<td>integer</td>
<td>0</td>
<td>&gt; 0</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>Rotating electric machines specifications for stepper motors IEC TS 60034-20-1:2002 (IEC) International Electrotechnical Commision</td>
<td>binary</td>
<td>N/A</td>
<td>Pass</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>Total volume</td>
<td>$in^3$</td>
<td>&lt; 400</td>
<td>&lt; 25</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>Rating of “device attractiveness” by class focus group</td>
<td>avg. score</td>
<td>&gt; 3/5</td>
<td>&gt; 4/5</td>
</tr>
<tr>
<td>9</td>
<td>6</td>
<td>Total weight</td>
<td>kg</td>
<td>2.0</td>
<td>0.5</td>
</tr>
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2.6 Project Management

The Gantt chart in Figure 7 gives an overview of the project schedule.
<table>
<thead>
<tr>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>2</td>
<td>9</td>
<td>16</td>
<td>23</td>
</tr>
</tbody>
</table>

- **Design Report**
- **Problem Understanding**
- **Concept Generation**
- **Concept Selection**
- **Concept Embodiment**
- **Design Refinement**
- **Peer Report Grading**
- **Prototypes**
- **Mockup**
- **Proofs of Concept**
- **Initial Prototype**
- **Initial Prototype Demo**
- **Final Prototype**
- **Final Prototype Demo**
- **Prototype Expo**
- **Presentations**
- **Critical Design Review**
- **Final Presentation**

Figure 7: Gantt chart for design project
3 Concept Generation

3.1 Mockup Prototype

Working on the mockup allowed us to determine the ideal size of the device. After the interview we had the option of making a larger table-top design or something that would fit comfortably in a hand (or both hands). We decided that a simple handheld device would be best. We were also able to come to the conclusion of a dedicated switch/lever/button to activate cutting. Originally, we were planning on working the cutting mechanism through a system of downward pressure applied by the user. Inspecting our mockup showed us how easy it would be to accidentally cut the fabric if we went this route. Figure 8 shows a side view of our design. You can note the "spool of fabric" that in our actual product would unroll on the working surface.

Figure 8: Side View
Figure 9 displays a front view. Note the dowel in the back to provide dual-handed control of the device.

Figure 9: Front View

Figure 10 shows the scale of the product. It should be a discrete handheld device.
Figure 11 gives a good view of the wheel to provide mobility. The movement mechanism will have to make it simple to travel in a straight line, so a wheel that allows full rotation about the z axis, as shown, may not make it into our final product.
3.2 Functional Decomposition

Figure 12: Function tree for Cloth Machine, hand-drawn on tablet
## 3.3 Morphological Chart

### Figure 13: Morphological Chart for Cloth Machine

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloth should adhere to</td>
<td>Spray give mechanism&lt;br&gt;Glue tank&lt;br&gt;Adhesive roller in front of fabric</td>
</tr>
<tr>
<td>paper</td>
<td>dispenser</td>
</tr>
<tr>
<td>Cloth doesn’t curl</td>
<td>Tension sensor&lt;br&gt;Central amount of fabric dispensed&lt;br&gt;Vertical dispensing</td>
</tr>
<tr>
<td></td>
<td>(against gravity)</td>
</tr>
<tr>
<td>Cuts cloth</td>
<td>Brake @ end of tool&lt;br&gt;Trigger/lever that acts on scissors @ end</td>
</tr>
<tr>
<td></td>
<td>Handle (not on actual handle) to cut (improve safety)</td>
</tr>
<tr>
<td>Switching out cartridges</td>
<td>Spring mechanism or snap-fit&lt;br&gt;Cordboard sensor&lt;br&gt;Remote controlled color</td>
</tr>
<tr>
<td></td>
<td>chooser</td>
</tr>
<tr>
<td>dispenses fabric</td>
<td>Indented wood @ end of panel&lt;br&gt;Two straight planks guiding the fabric</td>
</tr>
<tr>
<td>by rolling slips</td>
<td>Computer vision grid (or normal grid) to detect if in lines</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[Image of the chart]
3.4 Alternative Design Concepts

3.4.1 Cloth Machine

Figure 14: Preliminary sketches of Cloth Machine concept
Solutions from morph chart:

1. Cloth should adhere to dissolvable paper
2. Cloth doesn’t curl
3. Cuts cloth

Description:
The cloth machine has a plank with a blade attached to the leading end and a handle attached to the far end. There is a cartridge containing the fabric strips on a roll inside it. At the leading edge, there is also a blade used to cut the fabric when the user is done. There is also a motor on the cartridge, to control the rate at which fabric is dispensed and to also control the tension in the fabric.
3.4.2 Double Gun

Figure 16: Preliminary sketches of double gun concept
Solutions from morph chart:

1. Cloth should adhere to dissolvable paper
2. Cloth doesn’t curl (incorporation of tensor sensor)
3. Cuts cloth (lever blade)
4. Switching out cartridges (toilet paper spring mechanism)

Description:
The double gun cloth dispenser has a replaceable roll of fabric that can be easily changed out via a spring mechanism, similar to that of a toilet paper spring rod holder. The fabric from the replaceable roll goes through a tensor sensor that is sandwiched in between two fixed gears that lead the fabric out through a narrow opening. The tensor sensor stops the device from dispensing fabric by triggering a closure at the opening via a pulling mechanism. There are two blades fixed at the top and bottom of the opening. A lever near the tip of the device can be pushed downwards, pulling the top blade downward to cut the fabric. The handle of the device acts both as a handle and a container for the liquid adhesive that can be dispensed through a spraying mechanism.
3.4.3 Scanner-Stripper

Figure 18: Preliminary sketches of Scanner-Stripper
Solutions from morph chart:

1. Glue Box to dispense adhesive to area before fabric is placed
2. Cloth placed right down, device itself moves so cloth doesn’t pull
3. Drop down blade to cut fabric
4. Removable top that can hold a variable number of cartridges at desired locations
5. Device moves in a straight line

Description: The Scanner-Stripper slides across the work-space on air-hockey-like supports. It doesn’t make contact with the surface and doesn’t run the possibility of scrunching up the paper or tracking in the glue. It also provides an unprecedented amount of mobility for a unit of it’s size. The thread extrudes from the bottom/front of the device onto the desired space. When needed, the thread can be cut by a drop down blade. Easy replacement of thread is possible by dropping spools in the top and clamping them into the desired location. As many, or as few, threads can be used as desired. Adhesive is extruded from the bottom of the device through a ”glue box”. 
4 Concept Selection

4.1 Selection Criteria

Following is the chart we used to determine the relative importance of our measurement criteria. This is known as the Analytic Hierarchy Process.

![Analytic Hierarchy Process (AHP) to determine scoring matrix weights](image)

Figure 20: Analytic Hierarchy Process (AHP) to determine scoring matrix weights
4.2 Concept Evaluation

Using the data from the previous table, we weighed our three designs against one another. The "Cloth Machine" was used as our reference design.

<table>
<thead>
<tr>
<th>Alternative Design Concepts</th>
<th>Cloth Machine</th>
<th>Scanner-Stripper</th>
<th>Double Gun</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection Criterion</td>
<td>Weight (%)</td>
<td>Rating</td>
<td>Weighted</td>
</tr>
<tr>
<td>Cuts Cloth</td>
<td>20.64</td>
<td>3</td>
<td>0.62</td>
</tr>
<tr>
<td>Cloth Doesn't Curl</td>
<td>23.73</td>
<td>3</td>
<td>0.71</td>
</tr>
<tr>
<td>Cloth Adheres to Surface</td>
<td>16.3</td>
<td>3</td>
<td>0.49</td>
</tr>
<tr>
<td>Cartridges Can Switch In and Out</td>
<td>3.21</td>
<td>3</td>
<td>0.10</td>
</tr>
<tr>
<td>Dispenses Fabric Strips Parallel to One Another</td>
<td>9.29</td>
<td>3</td>
<td>0.28</td>
</tr>
<tr>
<td>Environmentally Friendly</td>
<td>26.83</td>
<td>3</td>
<td>0.80</td>
</tr>
<tr>
<td>Total score</td>
<td>3.000</td>
<td>2.858</td>
<td>2.937</td>
</tr>
</tbody>
</table>

Figure 21: Weighted Scoring Matrix for choosing between alternative concepts

4.3 Evaluation Results

We decided to pursue a simple, fabric dispensing design due to its ability to perform multiple tasks, intuitively and easily. One of our prime goals is to create a device that can be easily learned and handled by multiple users in little time. That being said, we believe that the Cloth Machine’s simple, yet robust, design would be easiest to adapt to because its different components (handle, lever for cutting, and toilet paper spring tube) are almost universally familiar across many different cultures. Our main target consumers are American fashion students and instructors, so we are confident that the different mechanisms of our device would be easily learned because we chose components that most Americans grow up using. For example, the Cloth Machine design, with its cart-roller design and u-shaped handle is the most intuitive design, since the handle resembles that of a drawer handle. The user would simply pull back using the handle to instigate fabric dispensing on a flat surface with strips parallel to one another. As such, this design scored highest for the criterion ”Dispenses Fabric Strips Parallel to one another.” Furthermore, using a spool of fabric that rotates as the user pulls back on the device helps with preventing cloth curl due to tension. Also, although we hadn’t designed a way to switch different spools of fabric in and out of the device, the simply design of this device provides much more leeway for implementing a mechanism for this purpose than the other designs. The alternative designs have enclosed housings for the spool and adhesive, which are much more difficult to general alterations to. That being said, because the design of the device is simple, we will focus on maximizing the quality of the mechanisms while
leaving much room for adaptability and improvement as we continuously brainstorm and build off of previous prototypes. For example, we have yet to come up with a good adhesion-system for our device and plan to implement one. This requires that we don’t over-complicate our current design to ensure that we are able to make good iterations as we delve deeper into the design-thinking process. The Cloth machine was scored highest for the cutting criteria this reason. Lastly, we decided that the cloth machine has the most potential of being environmentally friendly since the simplicity of the design allows us to further brainstorm different kinds of adhesive we could use: liquid vs tape. The other designs were predicted to require a liquid adhesive. With more research on the different types of adhesive, we could make a more informed and less constrained decision for what we believe is most environmentally friendly and sustainable.

4.4 Engineering Models/Relationships

Model #1: By using surface area/volume we can find the amount of glue necessary to lay down a garment. This will allow us to determine the size of the glue tank we attach to our device to provide the ideal amount of convenience to the end user. For instance, by modeling a garment as a 2-ft by 1.5-ft rectangle, and our path as 0.5 inch strips of fabric. We can determine the total amount of glue necessary, if we apply an even coat. Assuming a 1/32 inch thick coating [1] will give us the volume of glue necessary to lay a single garment. In the figure shown, l is length, w is width, and h is height.

![Volume of a Rectangular Prism](https://www.onlinemathlearning.com/volume-rectangular-prism.html)

Model #2: We plan on attaching our spool of fabric to our device using a similar design to a toilet paper tube. As such, we will have a pair of telescoping cylinders connected with a spring. By using Hooke’s Law, we will be able to determine the proper stiffness of spring we will need. The criteria is based on the amount of force we feel is appropriate for our end user to have to apply to displace the device enough to insert a new fabric cartridge. This has to be done in such a way that the chance of accidental ejection is minimal to non-existent. In the equation shown in figure 4, below, F represents force, k represents the spring constant, and x represents displacement.
Figure 23: Model 1: Finding the right spring for our cartridge-release mechanism. Source: https://phys.org/news/2015-02-law.html

Hooke's Law:

\[ F_{spring} = -kx \]

Spring constant \( k \)

It takes twice as much force to stretch a spring twice as far.
Model #3: Our design utilizes rollers to control the dispensing of the 1/2 inch fabric. For this part of our prototype, we have to consider the friction coefficient and weight of our device and the estimated force the user applies at the front of our device to dispense the fabric and tape.

1. Estimated weight device: 4 lbs.
2. Static Friction Coefficient of rubber rollers: 1.16.
3. Desired Acceleration: \(2 \text{ in} \text{ sec}^2\)

\[ F_{kmax} = 0.5 \times m \times g \times \mu_s \]
\[ F_{kmax} = 0.5 \times 4 \times (1.16) = 2.32 \text{ lbs.} \]

Desired Acceleration = \(\frac{F_{kmax}}{m}\)
\[ \frac{2 \text{ in}}{\text{sec}^2} > \frac{1.37}{4} = 0.58. \]

Seeing that our applied acceleration to move the device exceeds the maximum frictional force, we must increase the weight of our device or require more applied force from the user in order to avoid slipping.

5 Concept Embodiment

5.1 Initial Embodiment

These are our assembly drawings with front, top and right views. These were inspired by a cart design. The second drawing is an isometric view with a bill of materials and the last image is an exploded view with a call-out to the bill of materials.
Figure 24: Front view, top view and right view of our assembly.
Figure 25: Assembled isometric view with bill of materials (BOM)

<table>
<thead>
<tr>
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<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QTY.</th>
</tr>
</thead>
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<td>1</td>
<td></td>
</tr>
<tr>
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<td>2</td>
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</tr>
<tr>
<td>3</td>
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<td>16</td>
<td>98649A510</td>
<td>8</td>
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</table>
5.1.1 Model Based Design Rationale for at least 3 Initial Prototype Components

Choosing to use tape for this model: The sticky glue we were using does not dry fast enough to catch the cloth and hold it down without making a mess. It is also not the most efficient way to dispense an adhesive. This is because it is very difficult to actually moderate how hard we are squeezing the tube of glue with our hands. Therefore, the ability of this design to transfer effectively between users, with consistent results, is poor.

Rollers: Because our device is so dependent on rolling with minimal friction and resistance, we had to add many rollers to our design. In one of our previous iterations, when the spool was working by itself, it was tugging on the fabric and stretching it. We do not want this and want a way to eliminate tugging so the fabric doesn’t deform. To do this, we had to add many rollers to facilitate spinning and to make fabric and tape dispensing more seamless.

Bearing: The bearings allow the spool to spin freely without stopping. We’re using ball bearings specifically so that surfaces between the shaft and spool are not in direct contact, but instead are separated by ball bearings which in the end allow the spool to spin with the least amount of friction. Similar to rollers, adding this design element will help us in dispensing fabric, as well as dispensing tape as easily as possible.

PROTOTYPE PERFORMANCE GOALS:

1. T-shirt Strip Dispenser (TSD) lays down 5 2-foot strips of t-shirt in less than 1 minute.
2. TSD performs test in Goal 1 with all strips well adhered (resists gentle tugging along strip).
3. User can replace spool and replenish adhesive within 40 sec.

5.2 Proofs-of-Concept

The spring proof of concept is based on our original design of a wheeled device that supports the spool on top. If the supports that nest the spool are rigidly fastened to the device, then we will need some way to switch spools in and out. Enter our first proof of concept. This device functions like the support of a toilet paper roll. Two telescoping cylinders, connected with a spring, can be compressed to let the user switch rolls, but hold firm in its resting state.
Figure 27: Spring mechanism for holding and releasing thread spool
The two figures below show an alternate design attempt based on a tape-dispensing device. This device allows the fabric spool to rotate freely on a dowel, and has an additional support for a roll of tape. We discovered double-sided biodegradable tape and recognized the chance to upgrade our device’s functionality.
Figure 29: Design of the frame, inspired by a handheld tape dispenser. Separate dowels to hold fabric spool and double-sided tape
To allow the supports on the bottom half of the device to remain fixed, while still allowing the user to change spools we decide to separate the top and bottom halves of one of the devices sides. The top half would press fit onto the dowels and clamp onto the rigid half of the side-support. This concept is tested in Fig. 31. We were looking to see if the clamps were strong enough to hold under use conditions.
5.2.1 Design Explanation

After exploring both design ideas, our original rolling design and the alternate handheld design, we had a second interview with our device’s consumer. She expressed support for the rolling design. The device could potentially be in use by a single individual for extended periods of time. Therefore, the added comfort of not having to hold up a weighted device is a great benefit. The biggest change we are implementing after our prototype demonstration is rollers. The process of laying the cloth down flat, consistently, is a significant challenge. By incorporating rollers into our design we hope to lay the cloth down flat and press it firmly to the adhesive we are using. Additionally, we have decided to move away from using glue for our subsequent prototypes. The glue dispenser design has proven itself to be very inefficient. Major drawbacks include: It is not user friendly, it requires attention to be split between two tasks, and the constant squeezing to dispense the glue would not be acceptable for someone with fine-motor impairments. In terms of pure performance, we noticed: it is hard to control how much glue comes out at a time and the glue we used does not dry fast enough to hold the cloth in place. These improvements are based on visual and tactile feedback of how the initial prototype performed.
Figure 32: Diagram of how rollers lead yarn strip from spool to flat surface
Figure 33: Old iteration of design that we wanted to change
Figure 34: Old iteration of design that we wanted to change
As seen here, the glue design is inefficient and required too much work for your joints. We will not be using this design, and the model we have shown is a more legitimate reflection of where we want to head with our next prototype.

Have a good day!

6 Design Refinement

6.1 FEM Stress/Deflection Analysis

We chose a quarter inch shaft attached to the roller at the front of the device because that is where we are directly applying a load (by pressing down to dispense the cloth). Because this shaft takes on the most load, it will have considerable deflection. We used the default mesh because when we used a fine mesh, the study failed, so we thought the default mesh would be the best option, as shown in Figure 1. Since finer meshes indicate higher accuracy, we also thought that since our shaft is so small, and our load is so much bigger we didn’t need to worry about accuracy and therefore didn’t need to worry about our mesh size too much. Furthermore, the shaft has a simple, cylindrical geometry; thus, we predicted that the mesh on this part would have a smooth gradient. As such, a finer mesh is unnecessary for this analysis. We applied a 20 Newton load to the cylindrical surface on the shaft. This relatively high force accounts for the user accidentally applying too much weight to the device. Accounting for this would provide realistic deflection, stress, and strain results, providing more insight into how we can iterate our design to better resist such a significant load of 20 Newtons. It is also this reason that inspired our weak material choice: balsa wood. Our boundary conditions consist of one fixed end and a roller at the opposite end, which is indicated in Figure 1. In our prototype, the shaft has two ends that are fixed onto two brackets that prevent deflection at these locations. While applying fixed geometry at both ends would be ideal, we chose to apply a roller at one end to account for realistic behavior due to imperfections of fitting, material, and design. All in all, the choices made for the applied force, boundary conditions, and mesh size are all suited for the shaft’s simple geometry. That being said, our biggest concern with our shaft is failure due to large load. We would need to worry about deflection if it becomes failure in the center of the shaft, because if it breaks we cannot use our tool anymore. This would not be tolerable.

Our calculated factor of safety is $FOS = 15714$ using the von mises stress theory. Such a high Factor of Safety value indicates that the shaft should be able to withstand 20 Newtons of force. Our ultimate stress value came from Matweb.com.

The displacement, von mises stress, and strain plots are shown in Figure 2, Figure 3, and Figure 4, respectively.

- Maximum Deflection: $2.023e-01$ mm
- Maximum Stress: $9.724e+06$ N/m$^2$
- Maximum Strain: $2.273e-03$ N/m$^2$
Figure 35: Mesh, Applied Load (20 N), Boundary Conditions

Figure 36: Displacement Plot
6.2 Design for Safety

6.2.1 Risk #1: Slipping

**Description:** If the user applies too much pressure to the device, the base could split in half and the fracture can cut the user’s hand. Furthermore, hazardous tools on the platform that the user is laying the fabric strips on pose a serious threat to their safety.

**Severity:** The severity is **negligible** because even if you do ”hurt” yourself, it would not seriously injure you.

**Probability:** This is **unlikely** to happen as you would not need to apply this much pressure on
the tool.
Mitigating Steps: If we added a motor, the motor could do all of the work and dispense the fabric and the user would not have to apply much pressure at all.

6.2.2 Risk#2: Handle Falls Off

Description: If the handle comes loose, you can lose your balance while using this tool. This can cause your hands to accidentally slip and can cause you to make potentially dangerous contact with the surface.
Severity: The severity is negligible because you probably wouldn’t hit your hand hard on the surface.
Probability: This is likely to happen since the handle will be press-fit and loosen over time with frequent usage.
Mitigating Steps: We can use a stronger way to attach the base to the handle, such as welding or screwing.

6.2.3 Risk#3: Torso Injury

Description: It is possible that while using this you could accidentally lose balance and slide the tool into yourself and hurt your torso since it is coming towards you.
Severity: This is negligible in severity because you probably won’t hit your torso very hard.
Probability: This is unlikely to happen unless you are trying to go very fast.
Mitigating Steps: We advise the user to be steady and maintain balance while using this device. We discourage the user from rushing the laying down process. Furthermore, we plan to make the base of device parallel to the surface that the user is working on. The device itself, therefore, would be even and balanced so that the user does not need to move their torso in complicated ways to maneuver the device.

6.2.4 Risk#4: Fragile Tool

Description: This tool is fragile and if you accidentally step on it, it will destroy the entire object and its functionality.
Severity: This is a severe risk because it will ruin the tool completely.
Probability: This is occasional in probability.
Mitigating Steps: To mitigate this risk, be aware of your surroundings and don’t put the tool at foot level. If needed, we would need to alter our device material choice to something stronger than acrylic or wood. Perhaps having our parts made of metal could increase durability and strength to withstand large loads.

6.2.5 Risk#5: Catching Risk

Description: Long hair or jewelry can get caught in the rollers and cause injury.
Severity: This is a severe risk because it can lead to injury or death.
Probability: This is negligible in probability because it is very hard to get anything in the rollers
on accident since the clearance is so small.

**Mitigating Steps:** To mitigate this risk, always tie back long hair and beards and don’t have loose dangling jewelry.

It looks like Risk 4 is the highest priority which is the one where we are concerned with stepping on or damaging the device. Everything else is not very likely to happen or if it is, it is of negligible severity.
6.3 Design for Manufacturing

To modify the base, we used a draft angle of 3.00 degrees on all of the vertically oriented faces and through holes. Using an angle of 3.00 degrees allows for the removal of a mold much easier. We used the top plane for the reference angle. The direction of pull is upwards, normal to the top plane. The initial DFM analysis and iteration result are shown in Figure 6 and Figure 7, respectively.
When running the DFM Analysis for injection molding, the tape holder design failed the maximum wall thickness condition, as shown in Figure 7. The maximum thickness for injection molding is 0.5 in., which is the thickness of this part. However, the recommended thickness is less than or equal to 0.12 in. This means that our part is too thick to successfully be injected molded; thus, we have to seek another manufacturing process to create this part.

When running the DFM Analysis for mill/drilling, the tape holder passed all the rules, as shown in Figure 8. The tape holder is a circular, donut shaped design, making it possible to manufacture this part via milling and drilling.

Figure 42: Tape Holder: Injection Molding Analysis
6.4 Design for Usability

**Vision:** The functionality of the device is very streamlined and doesn’t rely on color as a marker of anything. Red-Green colorblindness would not pose a difficulty for the user. It could only cause complications if the customer wanted to use red or green cloth. Presbyopia, or an inability to see nearby objects with clarity, could cause a larger issue. Operation of the device relies on placing lines of fabric next to each other accurately. To help with this issue we could install physical guides that jut out from the front of the device, allowing the user to see exactly where the fabric will be placed in relation to the surface.

**Hearing:** No aspects of our design require the user to interpret any auditory stimuli. This device is presbycutia-friendly and even friendly for members of the deaf community. The design is largely focused on visual and physical means of control, and will not be used in an area where a problem could occur outside of the field of vision that would require some form of alarm.

**Physical:** A physical impairment such as arthritis or muscle weakness could pose a notable issue. The design relies on pressure applied by the user at the front of the device to ensure constant contact between the rollers and the surface. Users with some form of ailment in their hands may have trouble applying the downward force necessary for extended periods of time. We can fix this issue with weighted handles. While this would make carrying the device more of a task, the device
would by no means become ”heavy” (It currently weighs under 2lbs as is). Additionally, the device is on wheels, so there are no drawbacks when actually operating the device.

**Control:** The T-shirt strip dispenser requires some fine-motor-control to keep the device straight when running lines of fabric. The wheels we are using allow free rotation about the z-axis, so they need to be held straight or the device will swivel off path. This could certainly be an issue if the customer requires very straight lines for their design, but doesn’t have the necessary dexterity, for any reason. We can solve this with the physical guides, mentioned to help with eye impairments, and wheels that can lock in a straight line.

## 7 Discussion

### 7.1 Project Development and Evolution

*Does the final project result align with its initial project description?*
  - Answer

*Was the project more or less difficult than expected?*
  - Answer

*On which part(s) of the design process should your group have spent more time? Which parts required less time?*
  - Answer

*Was there a component of the prototype that was significantly easier or harder to makeassemble than expected?*
  - Answer

*In hindsight, was there another design concept that might have been more successful than the chosen concept?*
  - Answer

### 7.2 Design Resources

*How did your group decide which codes and standards were most relevant? Did they influence your design concepts?*
  - Answer

*Was your group missing any critical information when it generated and evaluated concepts?*
  - Answer

*Were there additional engineering analyses that could have helped guide your design?*
  - Answer

*If you were able to redo the course, what would you have done differently the second time around?*
  - Answer

*Given more time and money, what upgrades could be made to the working prototype?*
  - Answer
7.3 Team Organization

Were team members’ skills complementary? Are there additional skills that would have benefited this project?

– Answer

Does this design experience inspire your group to attempt other design projects? If so, what type of projects?

– Answer
Bibliography